Active Galactic Nuclei: from Central Engine to Host Galaxy
ASP Conference Series, Vol. xxx, 2003
S. Collin, F. Combes, and I. Shlosman

Chandra Observations of Three SDSS Quasars at z≈6

D. A. Schwartz
Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge MA 02138

C. C. Cheung, J. F. C. Wardle
Physics Department, Brandeis University, Waltham, MA 02454

1. Observations

The Sloan Digital Sky Survey (SDSS) quasars at redshift z ≈ 6 (Fan et al. 2001) are the most distant condensed objects known in the universe. X-ray observations of them are of great importance; e.g., to study the cosmic time evolution of X-ray emission and to assess the detectability of quasar X-ray emission at even larger redshifts. All three quasars were easily detected in X-rays even in these relatively short observations (Table 1). However, as shown in Schwartz (2002c), *none were totally isolated point sources.*

Table 1. *Chandra* Observations of the SDSS quasars at redshift 6

Name[a]		Time	Core		Core	Jet		Remarks
SDSSp	z[a]	ksec	Cnts	L^b_{core}	α_{ox}	Cnts	L^b_{jet}	
J083643.85+005453.3	5.82	5.686	21	2.3	1.66	< 6.3	<0.70	Nearby Source
J103027.10+052455.0	6.28	7.942	6	0.55	1.79	<6.3	<0.59	Core not a Point
J130608.26+035626.3	5.99	8.160	16	1.3	1.65	7[c]	0.57[c]	Nearby Jet

[a]Fan et al. 2001 [b]Rest frame 2 –10 keV luminosity in units of 10^{45}ergs s^{-1}. We use H_0=65, Ω_0=0.3, and Ω_Λ=0.7 [c]Significant detection, but jet identification not certain

We specifically searched for an X-ray jet in these quasars, following the recognition (Schwartz 2002a,b) that *if* X-ray emission observed from radio jets at modest redshift is due to inverse Compton (IC) scattering on the Cosmic Microwave Background (CMB), then similar jets will have essentially the same surface brightness at arbitrarily larger redshifts, and may serve as "beacons" from the distant universe. We find an extended feature 23″ from the quasar SDSS 1306+0356, (Fig. 1, left) which may be such a jet. We can explain the emission as IC/CMB, assuming that the intrinsic properties of the system are similar to other X-ray jets (Fig 1, right).

In May 2002 we carried out a VLA target-of-opportunity observation of SDSS 1306 at 1.4 GHz. A two hour observation in the A configuration gave upper limits to either the quasar core or the jet of 0.1 mJy (3σ). A recent paper by Ivanov (2002) found a 23rd magnitude galaxy at the location of the jet feature. Both of the above mitigate against the extended source CXOU J130609.1+035643.5 being a jet associated with the quasar. A deep, 120 ksec, *Chandra* observation has been approved for cycle 4 to confirm or refute the jet identification.

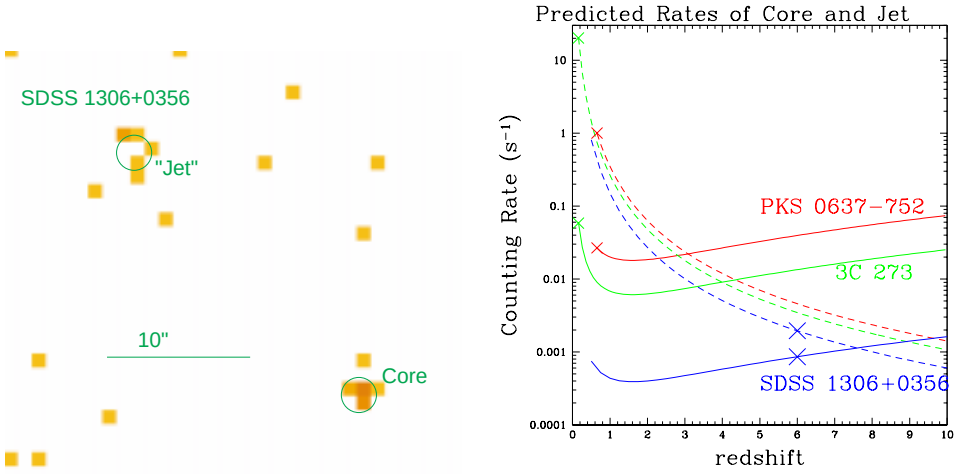

Figure 1. (Left) The 0.5 to 7 keV X-rays from SDSS 1306 binned by 1″. The circle is the 95% encircled energy diameter, so the feature we call a jet cannot be a single point source. (Right) The counting rates of IC/CMB jets, (solid lines) would remain roughly constant at any redshift, changing only with the small solid angle change and K-correction. The crosses plot the observed values at the actual redshifts. The cores, (dashed lines) change as D_{lum}^{-2}, so that at redshift z=1, SDSS 1306 would actually have the lowest jet to core ratio of these three objects.

2. Conclusions

Note that if the flux of these quasars had been measured within a 60″ circle, as commonly done for low redshift quasars using *ROSAT*, then their α_{ox} values would seem smaller (i.e., flatter optical to X-ray slope) by ≈0.15 due to nearby contaminating sources. Both the point-like source SW of SDSS 0836, and the extended core of SDSS 1030 (Schwartz 2002c, Fig 2), should also be considered as possible X-ray jets. Observations of quasars with *Chandra* will be important to obtain spectral information uncontaminated by nearby sources and to search for jets and gravitational lensing.

Acknowledgments. This research was sponsored in part by NASA contract NAS8-39073 to the Chandra X-ray Center, and by NSF grant AST 99-00723 to Brandeis. We thank the VLA scheduling committee for their quick response to our ToO request.

References

Fan, X., et al. 2001, AJ, 122, 2833

Ivanov, V. D. 2002, A&A, 389, L37

Schwartz, D. A. 2002a, proceedings of "Lighthouses of the Universe," ed. M. Gilfanov, R. Sunyaev, & E. Churazov (Berlin: Springer), 538

Schwartz, D. A. 2002b, ApJ(Letters), 569, L23

Schwartz, D. A. 2002c, ApJ(Letters), 571, L71